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THE STATUS AND DISTRIBUTION OF PENINSULAR BIGHORN SHEEP IN THE IN-KO-PAH MOUNTAINS CALIFORNIA

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ABSTRACT

Peninsular bighorn sheep (Ovis canadensis cremnobates) were studied in the In-Ko-Pah Mountains, southeastern San Diego County, California from May through November, 1978. Historically, bighorn occupied many of the desert slopes of the Peninsular Range but now occur only in isolated populations. Recently, the In-Ko-Pah herd has apparently been excluded from otherwise desirable habitat by human activities (e.g., off-road vehicles, highways, poaching, possibly grazing) and a 20-year drought that has probably eliminated some water sources.

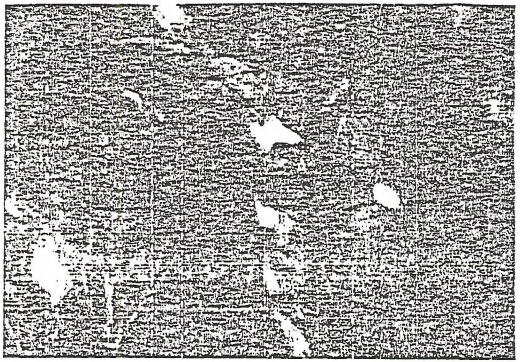
During the summer, the population is concentrated into an intensively used climax community which provides water, forage, and a reduced amount of disturbance. This herd has 80-100 animals and is characterized by few lambs and many older-aged individuals, having a ram:ewe:lamb ration of 40:100:1. Low lamb recruitment could be the result of decreased availability of nutrients and energy above that required for the maintenance of adults. It was hypothesized that this unhunted population is stable and near carrying capacity.

The current bighorn range covers approximately 40 square miles with the most intensive summer use occurring in a 10 square mile area where the five most important springs are located. Bighorn occur at a density of 5.3 sheep per square mile in the intensively used range. Sheep come to water every 1-2 days during the summer (June-August) and prefer steep

east-southeast facing slopes in rocky, enriched desert scrub at elevations between 1,300 and 2,000 feet where the major springs are located. Bighorn remain near escape terrain and appear to prefer slopes with an average plant cover between 6 and 11 percent.

Pellet group transect data indicate that deer (Odocoileus hemionus) and sheep avoid off-road vehicle trails; the frequency of pellet groups increased significantly with increasing distance from the trails ($r^2 = 0.59$, $P > 0.005$).

Area management is designed to encourage the expansion of the bighorn into its former range by restricting off-road vehicle travel and developing water sources. Food habit studies are now being conducted to determine the extent of bighorn-cattle food competition.



Frontispiece. Bighorn ram in the In-Ko-Pah Mountains, California. Photograph by L.L. Hicks, Bureau of Land Management, August, 1978.

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INTRODUCTION

Relatively little is known about the ecology of peninsular bighorn sheep (Ovis canadensis cremnobates) in southern California. Geographically, the race is situated between the Nelson bighorn (O. c. nelsoni) to the north and Weems bighorn (O. c. weemsi) to the south, with evidence of considerable overlap in ranges (Cowan, 1940). Over much of its range, peninsular bighorn populations have suffered from habitat loss and market hunting (Buechner, 1960).

Data on historical abundance of peninsular bighorn in the In-Ko-Pah Mountains of San Diego County are absent. However, annual water hole counts (3-day censuses) by Anza-Borrego State Park personnel and the Borrego Springs Natural History Association have documented a steady decline in the numbers of sheep occupying the In-Ko-Pahs during the last 4 years. Observations of ewes have declined from a high of 95 in 1976 to 47 in 1978 (Table 1). Similarly, the lambs numbers ranged from 15 in 1975 to 1 in 1977 and 0 in 1978.

Much of the occupied bighorn habitat in the In-Ko-Pah Mountains is included in the McCain Valley Resource Conservation Area managed by the Bureau of Land Management. Use of McCain Valley and adjacent areas by recreationists has increased dramatically within the last 8 years (BLM, 1978a).

Table 1. Results of bighorn sheep water hole census, In-Ko-Pah Mountains, 1975-1978

	1975	1976	1977	1978
Ram	14	19	20	17
Ewe	76	95	59	47
Yearling	7	7	2	6
Lamb	15	9	1	0
TOTAL	122	138	84	70

Much of this increase in human activity was as off-road vehicle (ORV) use in areas currently occupied by bighorn sheep. The decision by BLM to close many off-road vehicle trails in McCain Valley under the newly completed wildlife Habitat Management Plan (BLM, 1978b) generated much controversy among recreational groups. It became evident that more knowledge of the In-Ko-Pah bighorn herd was needed to properly manage the area, as well as the species.

Study Objectives

The study was designed to gather quantitative data on bighorns in the In-Ko-Pah/Jacumba Mountains study areas with the following objectives:

1) To obtain data on population demography, including age and sex ratios, recruitment rates, mortality factors and population trend.

2) To delineate the extent of the present bighorn range as well as movements and areas of high concentration within the range.

3) To quantify the habitat requirements of bighorn in terms of topographic and vegetative characteristics.

4) To determine the extent of dietary and habitat overlap between cattle and bighorn sheep.

5) To evaluate the extent of human disturbance to bighorns by recreationists.

6) To design a long-term study and develop techniques to continue effective observation of the herd.

Field work extended from May 23 to November 4, 1978. This period of study allowed time to become familiar with bighorn in the area and to document movements and behavior during the critical summer months. Field data were gathered by numerous 1 to 5 day backpack trips into the study area. Daily locations visited during the study are listed in Appendix 5.

Previous Studies on Peninsular Bighorn

Much of the information available of peninsular bighorn comes from the population inhabiting the Santa Rosa Mountains. Blong and Pollard (1968) have investigated summer water requirements, and Turner (1973) has studied physiological relationships of sheep in the area. Merritt (1974) has evaluated habitat utilization, and Jorgensen (1974) has reported on human disturbance in areas of that range supporting high densities of sheep.

Studies on bighorn in the In-Ko-Pah Mountains have been limited to surveys by Jorgensen and Turner (1973, 1974, 1975), and parasite studies by Russi (1976). Russi (1978) has also investigated a small herd of

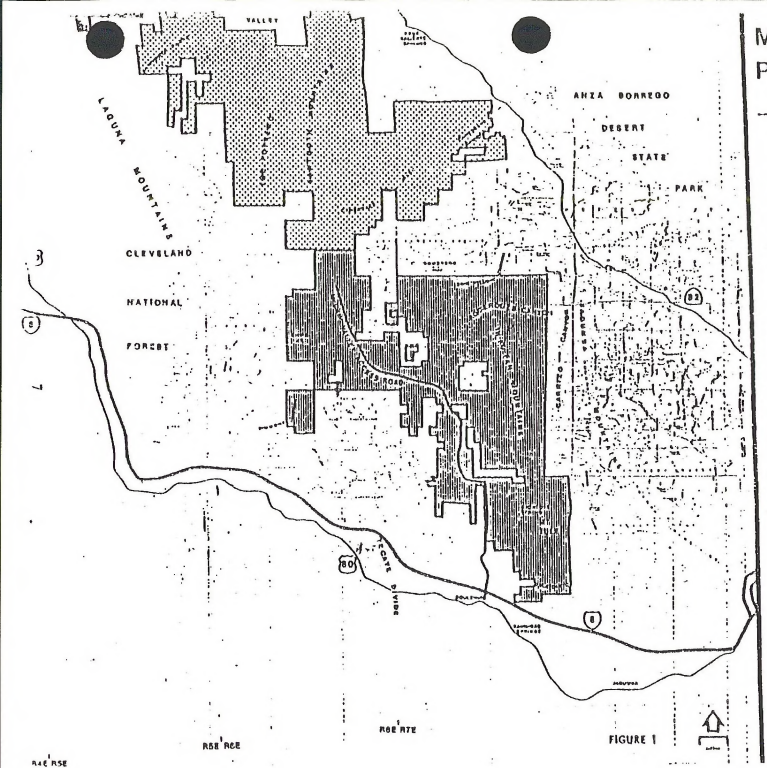
peninsular bighorn inhabiting the nearby Pinyon and Vallecito Mountains. Behavioral data on bighorn in the study area were compiled by Olech (1978). An ORV recreationist's opinion of the bighorn situation in McCain Valley is presented by Crandall (1974).

THE STUDY AREA

The study area is located in eastern San Diego County approximately 10 mi (16 km) north of the Mexican border, partly within the McCain subunit of McCain Valley Wildlife Habitat Area and partly within Anza-Borrego Desert State Park (Fig. 1).

Current sheep range in the area is a much reduced remnant of past distribution (Fig. 2). The In-Ko-Pah Mountain herd now occupies an area of about 40 sq. miles (106 sq. km) (BLM, 1978b), which includes the most rugged terrain to be found in the range. The area is dominated by a steep escarpment in eastern McCain Valley with side drainages running into Carrizo Canyon. Much of the sheep population occupies these steep east-flowing drainages. Carrizo Canyon (and Carrizo Gorge) forms the boundary between the Jacumba Mountains to the east and the In-Ko-Pahs to the west. Elevations range from more than 4,000 feet (2,500 meters) on top of the McCain escarpment to less than 900 feet (550 meters) in Carrizo Canyon. This change in elevation occurs over a distance of 4 linear miles (6.4 km).

Three vegetative communities, as classified by Cheatham and Haller (1975), are present in the study area. Moving up from Carrizo Canyon to Mt. Tule the following vegetative communities and characteristic plants would be encountered: Alluvial desert scrub (Tamarisk - smoke tree - Dalea spinosa), steep and rocky enriched desert scrub (brittlebush - Encelia farinosa, catclaw - Acacia greggii) and semi-desert chaparral (juniper - Juniperus spp. - buckwhat - Eriogonum fasciculatum).



MANAGEMENT PLAN

Boundary of McCain Valley Wildlife Habitat Area

McCain Valley Wildlife Habitat Area

- Ortiflamme Subunit
- Sawtooth Subunit
- McCain Subunit

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FIGURE 1

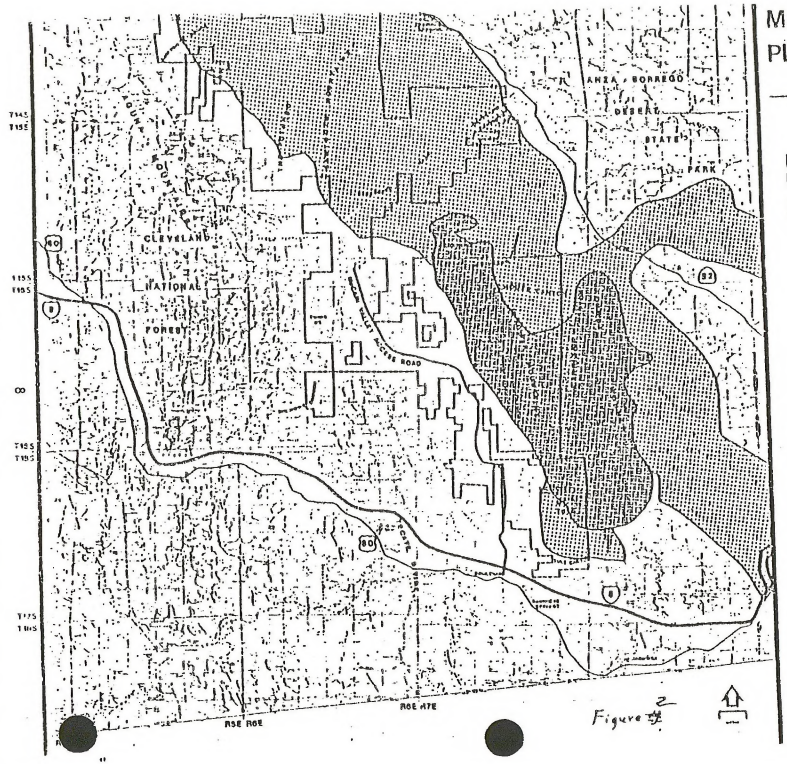
MANAGEMENT
PLAN
Boundary of McCain Valley
Wildlife Habitat Area
Bighorn Sheep
Distribution
Existing Sheep Habitat
Historic Sheep Habitat
ANZA - BORREGO
DESERT
STATE
PARK
CLEVELAND
NATIONAL
FOREST
T14S
T15S
T16S
T17S
R5E
R6E
R7E
prepared by
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Figure 2

Observation of Bighorn

Observations of bighorn were made with a 15-60x spotting scope and 10x35 binoculars. Data were recorded using both scan and focal animal sampling methods as described by Altman (1973). Scans were made on each band at 5-minute intervals, with tabulation of each member's behavioral activities. Time of day and duration of significant behavioral activities (e.g., fighting, bedding, mounting) were noted.

Three strategies were used in observing groups of bighorn. First, bighorn were observed from a concealed observation point to monitor bighorn movements and behavior around known water sources. These observations began in early morning and continued until darkness or until all sheep had left the area. The second method involved cross-country travel for several consecutive days to search for bighorns, define their routes of travel between watering sites, document ram movement to the rutting grounds, and to follow the more extensive travels by sheep groups during the cooler autumn weather. All of the side drainages from McCain Valley to Carrizo Canyon were surveyed for use by sheep. Portions of the Jacumba Mountains were also covered on foot to search for bighorn signs and possible lambing areas. Bands of sheep were follwed throughout the day and an attempt was made to monitor the night activities of groups. The third observation method was a helicopter survey, conducted on August 23 and 24, to search

the more remote areas for bighorn. Portions of upper Carrizo Gorge and the Jacumba Mountains were given priority on the aerial survey. A helicopter was also used to collect water samples from springs for analysis.

Habitat conditions at all bighorn sightings were characterized by location, slope, aspect, substrate, elevation, vegetation type, ambient temperature and distance to water and escape terrain. Slopes were measured with a Brunton compass. Elevations, distances and aspects were determined from topographic maps.

The age and sex of individuals seen were recorded using the criteria of Geist (1971), Bleich (no date), and Wells and Wells (1961). Ewes were difficult to age at a distance, particularly after 5 years when horn growth slows down or stops entirely (Geist, 1971). Consequently, ewes were often aged only as lambs, yearlings, and young or old adults. Horn and body anomalies were noted where observed.

Pellet Transects

Pellet group counts are a reliable means of determining the distribution and abundance of herbivores (Bennett, English, and McCain, 1940). Pellet transects were run perpendicularly to ORV trails and overlook sites in eastern McCain Valley to determine the occurrence of bighorn and mule deer (Odocoileus hemionus) in relation to the trails. No distinction was made between deer and sheep pellets found on the transects, since the

two species occur sympatrically in parts of the study area and the pellets cannot be accurately separated in the field.

Transects were 40 feet (12 meters) wide; three were 492 feet (150 meters) and three were 590 feet (180 meters) long. The number of pellet groups found and their distance from the road were recorded, as well as the number and distance of cattle feces encountered. Sampling sites were located at points overlooking Carrizo Canyon and its side drainages; transect locations are listed in Appendix 2. Transects were run in September.

Vegetation Analysis

Quantification of sheep habitat vegetative characteristics was accomplished with the aid of trained BLM vegetation specialists. Time and manpower constraints restricted analysis to three sites, all in the Jacumba Jim drainage. Sites #1 and #2 were used extensively by bighorn during the study and represent typical existing sheep habitat. Site #3 was chosen because of signs of past heavy sheep use (beds and pellets) and its close proximity to a heavily-used ORV overlook.

Both line-intercept and belt-transect methods were used to estimate relative density, frequency and cover of perennial plant species (Phillips, 1959). Annual species were not measured. Additional data recorded included species lists and evaluation of soil conditions and erosion.

Food Habits

Data on forage preferences of bighorn sheep in the study were obtained by direct observation. The species of plants and the portions selected were recorded. Additionally, the time and method used to obtain the plant (e.g., horning cholla or toppling barrel cactus) were noted.

Beginning in September, fecal samples from bighorn and cattle were collected for analysis for the Fecal Composition Analysis Laboratory at Arizona State University, Tempe. Bighorn pellet groups were collected the same day they were dropped. Samples were labeled by sex and age of individuals when possible. Objectives of the fecal study are to determine diet composition of bighorn sheep and cattle with emphasis on seasonal patterns and degree of dietary overlap between the two species over a 12-month period. Differences in forage preference by various bighorn age and sex groups will also be investigated.

RESULTS AND DISCUSSION

Bighorn Population Dynamics and Trend

A total of 123 bighorn groups, comprising 451 individuals, was observed. These figures obviously include repetitious sightings of animals over the period of study, but individuals seen repeatedly during the day were only counted once on the daily total. Average group size was 3.7 sheep/group, but ranged from 1 to 28 individuals.

The 451 individuals seen consisted of 127 rams, 317 ewes (including 2 yearlings) and 4 lambs (1 male, 2 female, 1 unidentified). Three adults seen at a distance could not be identified. The discrepancy between my counts and those obtained on the water hole census this year (Table 1) could be attributed to misidentification, late births or shifts in distribution of bands in the study area. Lambs and yearlings were not seen until relatively late in the study.

Table 2 summarizes the age and sex ratios of sheep observed at many different points in the range where all individuals had an equal chance of being seen, especially during the rutting season. Biases due to sighting one particular age or sex group were, therefore, at a minimum and total sighting figures were used in the calculations of age and sex ratios. A ram:ewe:lamb ration of 40:100:1 was calculated from the field observations.

Table 3 documents the age structure of the In-Ko-Pah rams using the ram age classification of Geist (1971). The table shows that class I rams (with less than one-half curl to the horns) and class II rams (one-half curl) comprise a small segment of the ram population, which is made up of predominately class III rams (three-quarter curl) and old class IV rams (full curl or greater). In summarizing the data thus far, the In-Ko-Pah bighorn herd appears to be characterized by low lamb numbers with a preponderance of older rams (and ewes) in the population.

Table 4 compares the age and sex ratios of the In-Ko-Pah herd with other populations of desert bighorn sheep. The comparison indicates that, while ram numbers apear to be consistent with other populations, the ewe:lamb ratio is significantly lower. Additionally, figures shown for the Santa Rose population of peninsular bighorn alsc indicate a recent drop in lamb numbers.

The percentage of rams in the population is not alarmingly low, but remains significantly less than other unhunted populations studied. Hansen (1967) reports that ram:ewe ratios on the Desert Wildlife Range approached 100:100 before hunting started in 1954; 10 years later, the ratio had decreased to 23:100. Of course, poaching has been a problem with this herd and could contribute to the low ram to ewe ratio (discussed later). Low lamb numbers in the study area cannot be attributed to low ram numbers, however, since the promiscuous breeding system of sheep

Table 2. Age and sex ratios of bighorn observed in the In-Ko-Pah Mountains, California, 1978

	(n)	Ratio
Total Adults : Lambs	444 : 4	100 : 0.9
All Ewes : Lambs	317 : 4	100 : 1.3
Adult Ewes : Yearlings	315 : 2	100 : 0.6
Adult Ewes : Lambs	315 : 4	100 : 1.3
Ewe : Ram	317 : 128	100 : 40

Table 3. Age structures of rams observed in the In-Ko-Pah Mountains, May-November, 1978

Ram Class	I.	II.	III.	IV.
Age (years)	2-3	3-6	5-8	8+
Number	6	7	41	62
Percent	5.2	6.0	35.3	53.5

Table 4. Comparison of age and sex ratios of desert bighorn sheep populations

Location	Ram:Ewe:Lamb	Source
Desert Wildlife Range (Nevada)	23:100:66	Hansen (1967)
Bill Williams Mtns. (Arizona)	75:100:38	Seegmiller (1977)
Black Mtns. (Arizona)	67:100:52	Walker (1978)
Arizona	123:100:48	Russo (1956)
Nevada	60:100:33	McQuivey (1978)
Death Valley (California)	100:100:85	Welles and Welles (1961)
Santa Rosa Mtns. (California)	30:100:30	Weaver and Mensch (197)
Santa Rosa Mtns. (California)	24:100:12	Cal. Dept. Fish and Game (1978)
Pinyon-Vallecito Mtns. (California)	40:100:40	Russi (1978)
Anza-Borrego State Park (California)	94:100:32	Jorgensen and Turner (1973)
In-Ko-Pah Mtns. (California)	40:100:1	Hicks (1978)

allows one ram to service many ewes. In addition, Table 3 shows that most of the rams in the area are of breeding age (three-quarter to full curl).

Buechner (1960) warns against the use of lamb-to-ewe ratios to judge population increase, especially for desert bighorn sheep, where a number of factors may bias lamb counts. Ewe-to-lamb ratios obtained from field counts indicate the rate of increment to population, but more data on actual lamb mortality is needed to accurately measure the reproductive effort. The observation of only four lambs during the study indicates that recruitment is exceedingly low in this population. Additionally, the low number of lamb carcasses found in the field may indicate that lamb mortality occurs either during pregnancy (abortion and in utero) death or shortly after birth while young are still in the lambing areas. This constitutes pre-recruitment mortality and is difficult to measure unless lambing is actually monitored.

The overall health of the population appeared good. Rams had the usual injuries attributable to fighting including broken horns and secondary infections on the face from rubbing. Many rams showed signs of old age such as cracked and broomed horns, swayed back and a distinct "paunch" to the belly. Lambs were active and well proportioned. Coughing or sneezing was rarely observed. A three-quarter curl ram was observed limping badly in Jacumba Jim Spring on October 3. The injury affected his movement but he still attempted to mount two ewes during the day. A ewe sighted

in Carrizo Canyon on November 3 was judged to be in poor condition, appearing gaunt with rough pelage. This ewe lagged behind the rest of the ewe band.

Fourteen sheep carcasses were found in the study area. Most were old carcasses with bleached and disarticulated bones, but three recent carcasses with hide and flesh still present were found. The cause of death could not be positively determined in any of the carcasses. The heads from several ram carcasses were collected for study. Seven of the fourteen carcasses were found at Blackwater and Diablo Springs. All were adults, but five carcasses had heads missing. Only one lamb carcass was found and its age was estimated at 6-12 months using the lower jaw and criteria by Cowan (1940) and Deming (1952). Carcasses of young animals do not persist for long periods in the field, because of the lack of ossification and the ability of carnivores and scavengers to consume or scatter the bones over wide areas (Murie, 1944). Consequently, the lack of lamb carcasses may be due in part to mechanical as well as biological reasons.

No incidences of poaching were observed during the field work, but scattered reports of shooting in the area were received. Poaching has been a serious problem with the In-Ko-Pah herd in the past. Taxidermist Gary Swanson was arrested in 1970 and charged with conspiracy to kill as many as 150 bighorn in the previous 4 years. Swanson was getting $3,000

a head to take shooters out to hunt rams in and around Anza-Borrego State Park (Tennesen, 1975). As many as 30 of the rams may have come out of the In-Ko-Pah herd. This loss has probably been repaired as nearly a decade of presumably much reduced hunting has since passed.

Predation is not a serious factor on the population. Potential predators observed in the area included golden eagles (Aquila chrysaetos), coyotes (Canis latrans), bobcats (Lynx rufus), and grey fox (Urocyon cinereo-argenteus). Mountain lion (Felix concolor) signs (tracks and scats were also seen. A coyote was observed following a ram and ewe in Jacumba Jim Springs on October 14. The coyote watched the pair but did not attempt to overtake them. Other sheep in the drainage watched intently as the coyote passed out of sight. Jorgensen and Turner (1973) reported the death of a young ram which possibly involved a coyote. They also noted that coyotes may feed on dead or dying lambs. Evidence that predator pressure is light is indicated by the observation of a lame deer successfully rearing a fawn near Sombrero Peak. It is unlikely both would have survived to their current ages if predator densities were high.

Few indications of disease were noted in the In-Ko-Pah population. The lungworm (Protostrogylus sp.), a serious parasite of bighorn sheep, can predispose the animal to pneumonia and death (Buechner, 1960). The severe implications of lungworm-pneumonia complex has been documented by Bear and Jones (1973) for the Tarryall herd in Colorado. In 1953, just after the Tarryall population had hit an all-time high of over 1,000

animals, a catastrophic die-off began and was positively related to lungworm infestations. The disease took 37 days to spread to every herd in the range and resulted in over 375 deaths within a period of 1 month. Following the epidemic, only 30 sheep survived the Tarryall die-off. A parasite survey by Russi (1976) reported a very low occurrence of lungworm and other parasites in the In-Ko-Pah herd.

Another disease that may be potentially serious to the herd is chronic sinusitis. The extent of this disease, which causes massive bone death (osteonecrosis) had only recently been documented by Bunch et al. (1978), who estimate the disease affects two-thirds of Arizona's total sheep population. The disease is transmitted by the sheep bot fly larva (Oestrus ovis) with secondary infections by corynebacteria. Infected animals experience extreme necrosis of the skull with open lesions and destruction of frontal bones and horn cores. The disease is terminal with death resulting from abscessation of the brain or starvation. A ewe found dead near Diablo Spring on August 10 was missing a horn and probably died of sinusitis and secondary infection. The carcass was in an advanced state of decay and further analysis was impossible.

It is important to note that free roaming wild animals seldom show progressive symptoms of disease, appearing healthy nearly to the day of death (Mike McCoy, San Diego Veterinarian, personal communication). As habitat becomes increasingly restricted, sheep could be forced into smaller areas, which would artificially increase the population density

as well as the possibility of disease transmission (Hanson, 1971). This situation may be occurring in the study area (discussed later). The treatment of any disease on a free-roaming herd of bighorn would be a difficult task.

Accidents are a factor in all sheep populations. Highway mortalities have been reported in the study area, which is bordered on the south by Interstate 8 and on the east by State Highway S-2. Most of the potential for sheep deaths comes from fencing erected near the highways. Welsh (1971) reports that ten rams died in a single stretch of highway right-of-way fence adjacent to Interstate 10 near Quartzsite, Arizona during a 2-year period. This spring, a report was received of sheep attempting to cross Interstate 8 near Myer Creek, in the Jacumba Mountains. Highway maintenance personnel questioned concerning sheep sighting near the highway had not seen sheep in the area since 1971. Russi (personal communication) reported seeing fresh sheep tracks near Interstate 8 following the 1976 flood.

A conservative estimate of the number of bighorn sheep inhabiting the In-Ko-Pah and Jacumba Mountains is between 80 and 100 sheep. This is definitely a "ball park" estimate, based on the pattern of "one-man water hole counts" used during the survey. By covering each water source during consecutive days in the field, it became apparent that bands did not quickly move from one spring to the next. This allowed an opportunity to tally animals in each drainage during the week. Of course, not all

springs received the same use, as will be shown later. During two consecutive field days in October, 39 different individuals were seen at Blackwater and Jacumba Jim Springs located at opposite ends of the summer use area. There was little chance of repetition between the locations. A more reliable estimate can be obtained by other census methods and is discussed later. The population trend appears to be stable to declining, based on the low lamb numbers and the preponderance of older individuals in the population.

Bighorn Distribution and Movements

During the study it soon became evident that bighorns were using some areas of the range much more than others. Of the total area used by sheep (ca. 40 sq. mi.) in the In-Ko-Pah and Jacumba Mountains, extensive and intensive areas of sheep use can be delineated.

Extensive areas of the range are those areas not supporting large numbers of sheep or are used only part of the year. These areas include:

1) The northern limit of the range near Sombrero Peak including upper Rockhouse Canyon where rams spend the spring and early summer before moving to lower elevations for the rut.

2) The southern section of the range near Mt. Tule where little sign was found but some potential for bighorn exists.

3) The portion of Carrizo Gorge (south of Sec. 6, T. 17 S., R. 8 E.) appears to support small groups of bighorn during the summer, including rams, ewes and lambs. Four bighorn (two rams and two ewes) were observed at an ephemeral seep in the drainage bottom in Section 7 on August 14. Several sheep were seen in the area during the helicopter survey of August 23 and 24. Tracks and pellets were found as far up as Tule Canyon during a hike through the gorge. The area near Tule and Walker Canyons contains many pools of water interspersed with thick vegetation. Cattle sign was also present.

4) The Jacumba Mountains from T. 16 S., R. 8 E., Section 7 south to the Mexican border. Sheep were frequently seen on the east side of the Carrizo drainage as cooler weather approached. The range has little available water in the form of dependable springs. Tracks and pellets were found near the old San Diego and Arizona Eastern railroad line, particularly near Goat Canyon (T. 16 S., R. 8 E., Section 32) and the spring located near the rail tracks in T. 17 S., R. 8 E., Section 17. The area may also include possible lambing grounds (discussed later). In addition, the area near Mountain Springs and Interstate 8 may be a possible route for immigrant sheep moving up from Mexico, as based on recent reports.

5) Finally, the areas north of Sombrero Peak including Inner Pasture, Indian Gorge, and Canebrake Canyon could support relict herds of sheep and should be surveyed further for sign. Reports from residents and ranchers in the area indicate that rams (possibly from Sombrero Peak) and ewes have been seen in the areas drinking from cattle troughs or moving along ridgelines. Portions of the area appear to be good sheep habitat and comparable to areas currently supporting bighorn.

The intensive portion of the range are those areas that support most (or all) of the animals for most of the year. This area includes a 10 square mile section of habitat starting at T. 16 S., R. 7 E., Sections 11 and 12, running directly south to Sections 35 and 36. It contains the five most important springs in the study area and constitutes a major proportion of sightings and activity observed during the study. The intensive range is bordered on the east by Carrizo Canyon and on the west by McCain Valley and the zone of heavy ORV activity. The area not only supports the ewes for most of the year, but also serves as the rutting grounds.

Using the lower limit of the population estimate (80 sheep) and the 15 sqare mile portion of the habitat actively used by bighorn (including the intensive range and the Sombrero Peak spring-early summer ram area), a density estimate of 5.3 sheep per square mile is derived. McQuivey (1978) has reported that bighorn densities in Nevada range from 0.3 to 6.0 sheep per square mile with an average of 1.9 sheep per square mile statewide.

The annual movement patterns in the study area can be summarized, based on this study and year-round observations by Russi (personal communication). There is no distinct winter or summer range in the study area. Rams concentrate around the Sombrero Peak area from March to July. Ewes concentrate in the side drainages of the intensive portion of the range all year, except for time spent on lambing grounds in February. During July, the rams move into the intensive range and the rut begins about August 1. [Continuing BLM studies may modify this conclusion.]

The preceding pattern has been established for the herd during a year with average precipitation. This year's unusually heavy rainfall occurred during the early part of the year. Rams were first observed near Sombrero Peak on May 23. Rams were seen in Rockhouse Canyon and Long Walk Canyon (T. 16 S., R. 7 E., Section 11) on June 27 and 28. These groups were observed moving south toward the intensive range. Rams were first seen in Jacumba Jim Spring on the annual water hole census during July 4 and 5. This is the first ewe area encountered by rams as they moved into the intensive range. It is reasonable to assume that rams entered the rutting grounds by July 1, a month early. Additionally, rams did not water at the usual springs (Macho or Grapevine) but rather drank from Bow Willow Creek which continued flowing due to the wet year. In summary, the increased precipitation and water availability altered both the time and route of ram movement to the rutting areas allowing the rams to travel lower in elevation and arrive earlier in the year.

The five springs located in the intensive section of the range are the focal points in the movement patterns of the In-Ko-Pah herd.

Much of the data gathered on water hole use and behavior by sheep are too detailed to be presented here, but a synopsis of seasonal use can be offered. During the hot summer months (June-August), sheep usually came into water between 10:30 and 12:30 PDT. Often several groups entered springs from different directions and remained near the water throughout the afternoon. Bedding, feeding and rutting activities occurred in the drainages. Interchange of individuals and splintering or merging of groups was observed. In later afternoon, groups left the spring, moving up the slopes to night bedding sites. Sheep were not observed drinking at night as reported by Blong and Pollard (1968). However, movement did occur at night if bands were not on exceedingly steep rock faces. Turner (1973) found that desert bighorn survived 20 percent loss of body weight after 5 days of water deprivation. Bighorn observed during the summer often had a distinct depression in the abdominal area as they came into water and left much more filled out. Sheep came into water every 1-2 days during the summer. During the height of the rut, rams moved from spring to spring and actively searched for ewes. Often solitary rams would arrive at a spring early in the day and wait for ewes to come in to water. During cooler weather (September-November), groups of rams and ewes took longer 2-3 day circular trips around a spring. The was evident for sheep observed in the Jacumba Jim drainage. The trips often penetrated the Jacumba Mountains before returning to watering sites.

Beginning in mid-September, tracks and sightings of sheep in Carrizo Canyon became more common, particularly in the lower elevations between the Jacumba Jim and Rockhouse side drainages. This also indicated that use of more extensive areas was occurring.

Possible lambing sites were investigated during the study. The exact location of the areas remains a mystery. Russi (personal communication) has identified one possible lambing site in the Jacumba Mountains directly south of Dos Cabezas Spring in Section 15. He reported seeing young lambs in this area in previous years. Hansen and Deming (1972) have determined that ewes seek lambing areas near choice food areas during clear and mild seasons and areas near water with rough, sheltered breaks during cloudy and cold seasons. The study area has many locations that satisfy both these requirements.

Bighorn Habitat Requirements

Table 6 summarizes the topographic characteristics of habitat used by bighorn in the study area. Sheep prefer the steep slopes approaching 100 percent incline for much of their activities, but occasionally were found on very level terrain, particularly the bottom of Carrizo Canyon. Sheep observed in flat situations usually appeared nervous, especially if steep slopes were some distance away. A 10 percent slope near Jacumba Jim Spring was used extensively by sheep as a route into the spring. Bedding would usually occur above the slope in steeper terrain. In-Ko-Pah

Table 6. Summary of bighorn habitat characteristics for the In-Ko-Pah Mountains herd, May-November, 1978 (N=123 observations)

Slope %

Interval	n	%
3-5	4	3.3
10-20	13	10.6
30-40	4	3.3
50-60	18	14.6
75-80	10	8.1
100	74	60.2
$\bar{x}$	76.3	
S.D.	33.7	

Aspect

Interval	n	%
N	12	9.8
NW	10	8.1
NE	4	3.3
S	13	10.6
SW	1	0.8
SE	33	26.8
E	33	26.8
W	17	13.8

Substrate

	n	%
Alluvial	2	1.6
Sandy	2	1.6
Rocky	119	96.7

Elevation (ft.)

Interval	n	%
950-1000	3	2.4
1100-1300	17	13.8
1380-1600	43	35.0
1700-2000	35	28.5
2100-2400	21	17.1
2600-4229	4	3.3
$\bar{x}$ =	1736	
S.D. =	438.1	

Distance to H_2O (km)

Interval	n	%
0-0.2	32	26.0
0.3-0.5	56	45.5
0.6-1.0	19	15.4
1.2-1.5	6	4.9
1.7-2.0	6	4.9
2.5-4.0	4	3.3
$\bar{x}$ =	0.6	
S.D. =	0.63	

Distance to Escape Terrain (km)

Interval	n	%
0	95	77.2
0.1	5	4.1
0.2	11	8.9
0.3	9	7.3
0.4	1	0.8
0.5	2	1.6
$\bar{x}$ =	0.06	
S.D. =	0.114	

bighorn were most encountered on east-southeast facing slopes. This apparently differs from the preference of Santa Rosa bighorn for north-facing slopes (Merritt, 1974). Sheep utilized the early morning sunlight on east slopes to feed and bed. Sheep were rarely seen on sandy or alluvial substrates and appeared to use those sites only in crossing drainages. Sheep were observed in elevations ranging from 950 feet (Carrizo Canyon) to over 4,000 feet (Sombrero Peak). A majority of sheep movements occurred at intermediate elevations (1,300-2,000 feet) where the major springs are located in the intensive range.

The figures shown for distance to water and escape terrain may be biased by observation of sheep near springs or in broken country. However, they do show the distance sheep will travel from known water sources and the preference shown for close proximity to escape terrain.

No correlation could be found concerning temperature or time of day and bighorn movements. While peak drinking activity did occur in late morning, sheep were seen at water at all times of the day except very early in the morning. As cooler weather returned, sheep would remain bedded until the slope came into sunlight. Observations indicated that groups bedded lower in elevation at night in the fall, possibly as a response to lower temperatures.

Tables 7 through 9 summarize the vegetative characteristics of three locations used by sheep in the study area. Bighorn appear to prefer slopes with scattered perennial shrub growth and average cover between 6 and 11 percent. Sheep avoided thick growth near springs, probably because it hindered a clear view of surrounding slopes. Conversely, deer were frequently seen bedding, feeding and drinking in thick vegetative growth. McQuivey (1978) has noted that sheep in Nevada will utilize pinyon-juniper zones if the trees are not abundant enough to affect visibility.

The following generalizations can be made concerning bighorn habitat requirements in the In-Ko-Pah Mountains. Sheep prefer steep broken terrain with rocky substrate between 1,300 and 2,000 feet in elevation. Sheep are usually on east to southeast facing slopes on escape terrain and often not far from water. Sheep range from alluvial desert shrub zones to semi-desert chaparral but are most often seen in steep and rocky enriched desert shrub with sparsely scattered perennial stands of brittlebush and catclaw that permit optimum visibility of surrounding slopes.

Human Disturbance

Human disturbance has many forms. These include hunting, introduction of livestock (and diseases associated with these animals), military

Table 7. Vegetative characteristics of site 1 used by bighorn in Jacumba Jim Drainage, In-Ko-Pah Mountains, July 1978

Species	Relative Frequency	Relative Density	Relative Cover	Importance Value[1]
Encelia farinosa	36.6%	18.8%	13.8%	69.2%
Ambrosia dumosa	24.3	18.6	6.9	49.8
Opuntia echinocarpa	18.3	6.1	10.3	34.7
Hyptis emoryi	4.3	—	20.7	25.0
Aristida spp.	2.1	16.0	3.4	21.5
Krameria grayi	2.1	2.8	13.8	18.7
Lotus scoparius	2.1	2.3	13.8	18.2
Echinocereus englemannii	8.1	2.8	6.9	17.8
Trixis californica	2.1	—	10.3	12.4

Location : T16SR7E SE1/4 SE1/4 Sec 14

Elevation : 1,300 feet

Slope : 10%

Aspect : S.E.

Average Cover : 11.1%

[1] Importance value = relative frequency + relative density + relative cover

Table 8. Vegetative characteristics of site 2 used by bighorn in Jacumba Jim Drainage, In-Ko-Pah Mountains, October 1978

Species	Relative Frequency	Relative Density	Relative Cover	Importance Value[1]
Encelia farinosa	73.3%	75%	20%	168.3
Ambrosia dumosa	7.2	12.9	15	35.1
Viguiera deltoidea	9.7	1.5	20	31.2
Bebbia juncea	2.6	2	20	24.6
Dyssodia porophyloides	4.6	0.8	15	20.4
Eriogonum fasciculatum	2.6	0.8	10	13.4

Location : T16S R7E NE1/4 NE1/4 Sec 23

Elevation : 1,600 feet

Slope : 100%

Aspect : N.W.

Average Cover : 7.2%

1 Importance value = relative frequency + relative density + relative cover

Table 9. Vegetative characteristics of site 3 used by bighorn in Jacumba Jim Drainage, In-Ko-Pah Mountains, October 1978

Species	Relative Frequency	Relative Density	Relative Cover	Importance Value[1]
Happlopappus propincuous	22.4%	11.7%	3.4%	37.5
Eriogonum fasciculatum	18.5	13.3	5.1	36.9
Lotus scoparius	6.0	17.1	6.1	28.2
Galium angustifolium	12.0	5.8	5.1	22.9
Simmondsia chinensis	12.0	2.8	6.8	21.6
Yucca schidigera	6.0	0	11.9	17.9
Stipa speciosa	2.1	14.0	1.7	17.8
Juniperus californicus	2.1	0.2	15.2	17.3
Ephedra californica	3.9	1.5	11.9	17.3
Salvia apiana	3.9	6.4	6.8	17.1

Location : T16S R7E SE1/4 NE1/4 Sec 22

Elevation : 3,230 feet

Slope : 50%

Aspect : North

Average Cover : 6.5%

[1] Importance value = relative frequency + relative density + relative cover

activity, construction of barriers across migration routes, appropriation of water sources for human use, agricultural and urban development and recreational activity (Blong, 1967; Duncan, 1960; Wilson, 1969; Van Den Akker, 1960; Dunaway, 1971; and Nelson, 1966).

Recreational use of public lands has increased steadily over the years (Stankey, et al 1976). While most of this use has been limited to designated trails and campsites, the trend nevertheless points to increasing human activity in areas of limited sheep habitat.

Evidence that human disturbance can be an important factor in wildlife distribution was presented by Ward et al. (1973) for elk. Elk kept a distance of 1/2 mile from campers, picnickers, and fishermen, and roads proved to be a barrier to elk movements. In Rocky Mountain National Park, off-road activity caused elk to leave open areas (Schultz and Bailey, 1978). Singer (1978) concluded that interrupted crossings of a road in Glacier National Park by mountain goats (Oreamnos americanus) was clearly related to visitor activity and vehicles.

Light and Weaver (1973) found that intense recreational activity and bighorn occupancy of an area were mutually exclusive in the San Gabriel Mountains. Recreational vehicles have caused sheep to abandon their traditional ranges. Deforge (1972) concluded that vehicle use in the South Fork of Lytle Creek (San Gabriel Mountains) had caused a reduction in the number of sheep occupying the area. Jorgensen (1974) reported a 50 percent reduction in bighorn activity on days with ORV traffic near

an important watering area in Anza-Borrego State Park. He also noted that bighorn and vehicles normally utilize the water source at the same time of the day.

Human disturbance affects bighorn sheep by increasing energy demands due to running and excitation. Ruminants are normally limited by their ability to obtain an adequate forage and energy supply. As their energy demands increase, regardless of range conditions, their reproduction output must decline, as well as health and growth rates (Geist, 1975).

The most significant effect of recreational activity on bighorn sheep in the study area occurs on the east side of McCain Valley on the McCain escarpment. Here a network of ORV trails has been created which brings people and bighorn into close proximity. The trails penetrate the upper portion of the intensive range used year-round by sheep. Additionally, a jeep trail through Carrizo Canyon has allowed vehicle access to important sheep habitat from below. The effects of recreational activity on bighorn sheep take three forms: noise, effect of trails, and vehicle/bighorn interactions.

Vehicle noise from McCain Valley was heard at every water hole monitored during the 3-day July water hole census. I observed mule deer leave a spring shortly after the noise started. Russi (personal communication) observed that sheep groups splintered and scattered as noise from approaching vehicles increased. Hunting also contributes noise. Shots fired

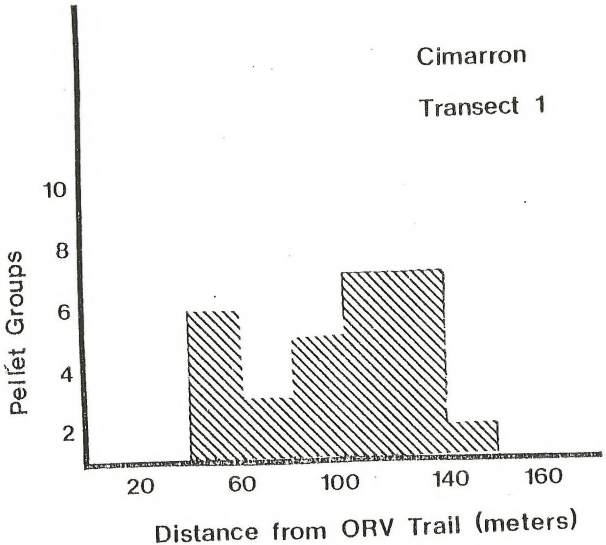
were heard near the east escarpment jeep trail. I was observing sheep near Jacumba Jim spring during the first day of deer season (October 14). At that time, a large number of sheep had grouped in the lower portion of the drainage. Poor weather contributed to a lower than usual hunter turnout, but 9-10 hunter groups were observed on the east side of McCain Valley on opening day of quail season (October 21). Probably the most significant effect of noise on bighorn was shown when Navy helicopters passed very low through the study area. Sheep in all cases jumped up from beds and on two occasions left the spring entirely.

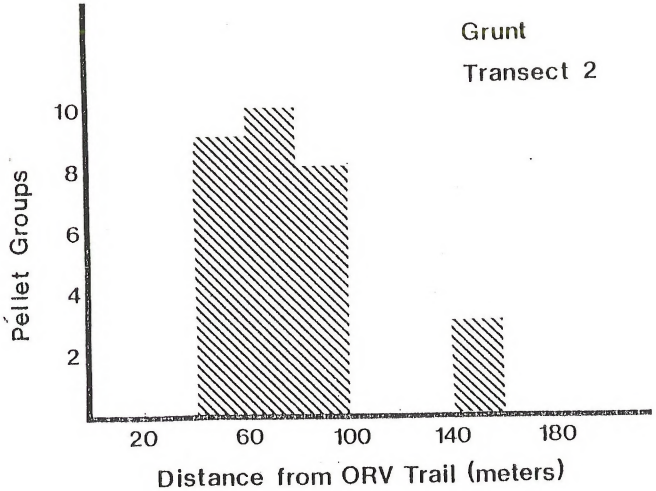
All pellet transects ran at six different ORV overlooks in eastern McCain Valley showed an increasing frequency of deer and sheep pellets with increasing distance from the ORV trails (Figs. 3-8). At four locations, there was no sign within 40 meters of the trail. At site number 6 above Jacumba Jim Canyon, the transect passed through an extensive sheep bedding area with many pellet groups. These pellets were very old, however, and the site appeared to have been abandoned by sheep. Figure 9 shows the results of regression analysis using the combined data from the six pellet transects. The regression is significant ($P < 0.005$) and indicates deer and sheep avoid off-road vehicle trails.

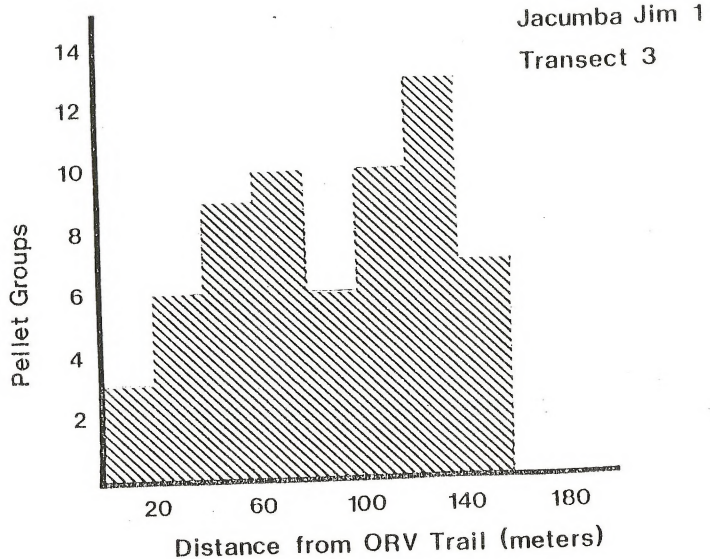
It is the nature of sheep to run uphill when alarmed. ORV trails on the east side of McCain Valley have the potential of bringing people and vehicles into areas above sheep which block their escape route and result in a more adverse reaction as sheep search for another uphill avenue of escape (Hicks, 1977).

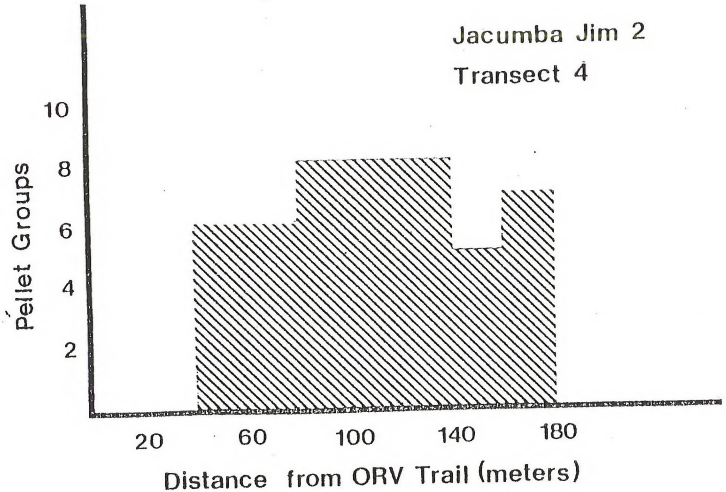
Figure 3-8

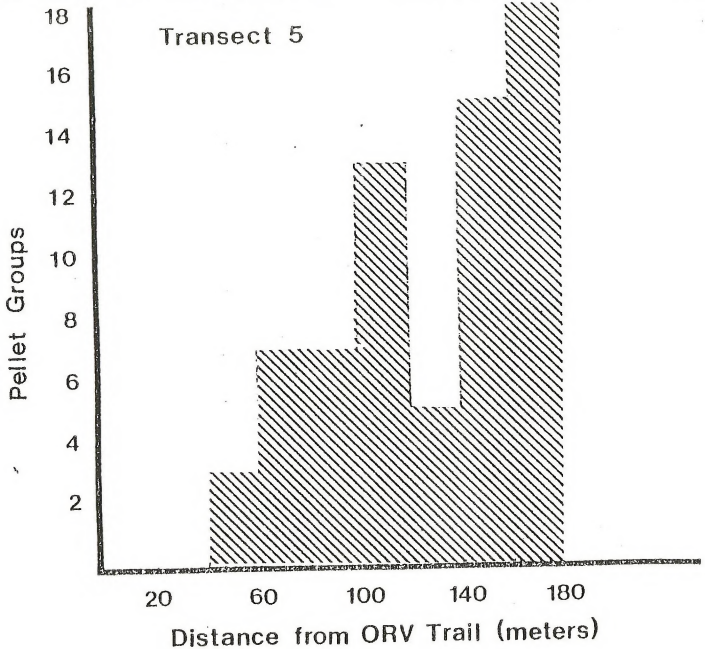
Results of pellet transects showing number of deer and bighorn sheep pellets with increasing distance from 6 ORV overlook sites east of McCain Valley. Location of overlooks in Appendix 2.


Cimarron
Transect 1
Pellet Groups
10
8
6
4
2
20
60
100
140
160
Distance from ORV Trail (meters)


Grunt
Transect 2
Pellet Groups
10
8
6
4
2
20
60
100
140
180
Distance from ORV Trail (meters)


Jacumba Jim 1
Transect 3
Pellet Groups
14
12
10
8
6
4
2
20
60
100
140
180
Distance from ORV Trail (meters)


Jacumba Jim 2
Transect 4
Pellet Groups
10
8
6
4
2
20
60
100
140
180
Distance from ORV Trail (meters)


Transect 5
Pellet Groups
18
16
14
12
10
8
6
4
2
20
60
100
140
180
Distance from ORV Trail (meters)

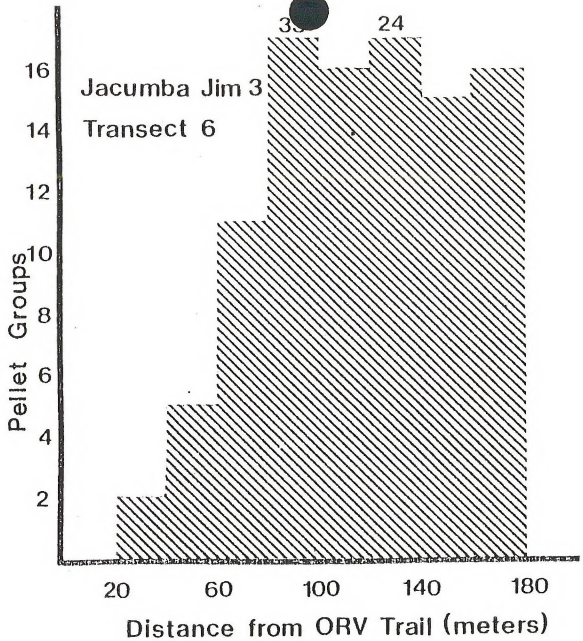
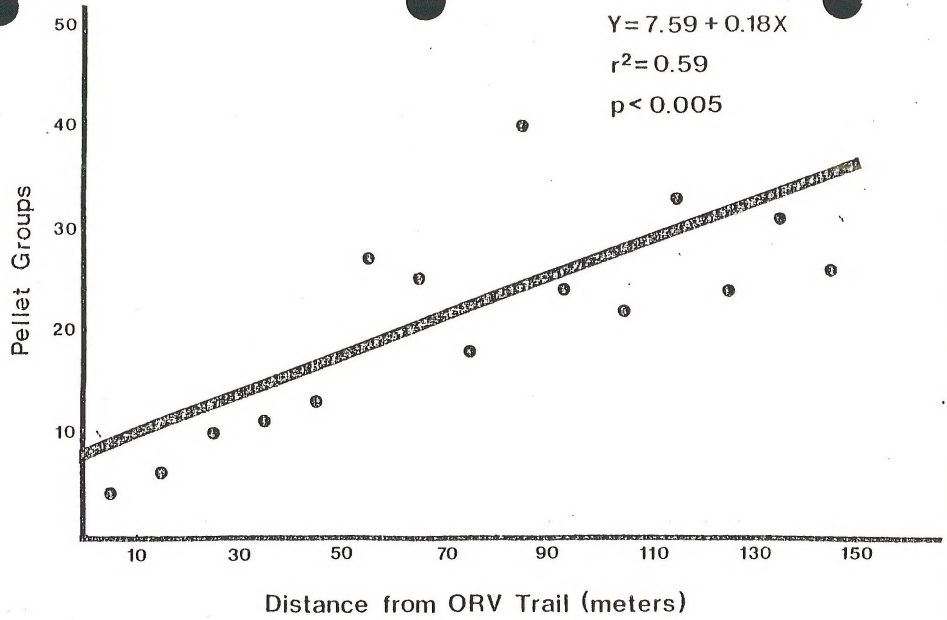

Jacumba Jim 3
Transect 6
24
Pellet Groups
16
14
12
10
8
6
4
2
20
60
100
140
180
Distance from ORV Trail (meters)

Figure 9

Regression of bighorn sheep and deer presense related to distance from 6 overlook sites east of McCain Valley.


Y= 7.59 + 0.18X
r²= 0.59
p< 0.005
Pellet Groups
50
40
30
20
10
10
30
50
70
90
110
130
150
Distance from ORV Trail (meters)

The reaction of bighorn to a vehicle was observed during eight encounters with sheep while driving along the Carrizo Canyon jeep trail. In all cases except one, immediate fast flight reactions were shown by sheep as they ran to the escape terrain on the steep canyon walls and climbed upwards an average of 100 meters. In one encounter, a ewe and two rams showed little concern for the vehicle once it had been stopped and the engine turned off. The unusual tolerance of the group can be attributed to the ewe who led the group. A similar situation is reported by Wells and Wells (1961). In all cases, the vehicle was located below or on an equal level as the sheep. On October 10, I inadvertantly split a group of bighorn crossing Carrizo Canyon in the afternoon. One ram was isolated on the east side of the canyon, separated from the rest of the group on the west side by my vehicle. This ram was very agitated and finally ran rapidly across the drainage to join the group after I had stopped and turned off the truck engine. Jorgensen (1974) describes a similar situation involving ewe-lamb separations.

Food Habits and Competition with Deer and Livestock

Cholla, barrel cactus and catclaw were the most heavily used forage species chosen by bighorn between May and November. Other commonly used species include the following (not ranked):

Mountain mohagany	Buckwheat
Agave	Galleta grass

Mesquite	Desert needle grass
Burrobush	Seepwillow

Russi (personal communication) has observed sheep eating over 53 species of plants in the study area. Results of the fecal analysis study will also elucidate forage species and their importance in bighorn diet.

Bighorn utilized barrel cactus flowers to a great degree in spring and early summer. Sheep actively sought the flowers, walking from plant to plant, sometimes toppling barrel cactus to obtain the flowers. Late in the study, utilization of the main body and roots of the plants was noted. Sheep spent up to 1/2 hour feeding on the downed plants. Cholla was also used extensively. Animals would break off sections with their horns and swallow up to 5-inch long portions whole. Catclaw was a widely used food item in drainages and near springs.

Mule deer were not commonly observed in the study area. The species occurs sympatrically with the bighorn but inhabits the upper elevations in the chaparral and oak woodlands habitats between McCain Valley and Carrizo Canyon. Deer were most often seen on terraced areas of the McCain escarpment between 3,000 and 4,000 feet in elevation. The paucity of deer sightings during the study indicated that deer were perhaps more uncommon than sheep in the area.

Cattle numbers are also low in the study area. While the exact number of head is not known due to strays and deaths, few cattle were observed in sheep country. Past stocking rates were higher and could have affected sheep distribution. Cattle are currently watered from developed springs in or near McCain Valley. Two locations where bighorn/cattle interaction occur are Macho Spring and Upper Carrizo Gorge. Cattle straying from a nearby developed spring (Tierra Blanca) have been observed near Macho Spring and the Sombrero Peak area. Sheep use this area and signs indicated recent use of this spring by livestock. As described earlier, Upper Carrizo Gorge has many pools with adjacent vegetation. Stray range cattle were observed near Tule Canyon on August 24. Fresh sheep tracks were also seen in this location. It is important to note that cattle sign was found in many areas of a 50 percent slope or greater; these areas are not included in grazing allocations. Nearly all of the springs used by cattle have significant signs of erosion and feces in the water with resultant algae blooms. This was especially apparent for the Upper Carrizo Gorge pools.

Population Status - A Hypothesis

Resource management based on hypothesis testing has been shown to be an important management tool (Wehausen, et al. 1977). The following hypothesis is presented to explain the population status and trend of the In-Ko-Pah herd. The formal hypothesis is as follows: The population of bighorn occupying the In-Ko-Pah Mountains is currently stable. A

relatively high sheep density on the intensively used portions of the range, and an abundance of old adult animals, support that the population is near carrying capacity.

Bighorn sheep are characteristic of stable, climax communities. Unlike moose or deer, bighorn disperse only as groups if they disperse at all (Geist, 1967). Dispersal is to other climax habitat, which usually is limited in a range. It is quite possible that stable, desirable habitats were once linked by migration routes but are now cut off by activities of man. The In-Ko-Pah herd is essentially limited to that terrain which provides water and forage year-round and a reduced amount of disturbance, that is, the intensively used section of the range. In this portion of the range, density is quite high, nearing six animals per square mile.

Stable sheep populations are characterized by extremely low mortality among older age classes, very high mortality among lambs, and a low turnover rate (Beuchner, 1960). Lamb mortality and decreased lamb quality results from decreased availability of nutrients and energy above that required for maintenance of adults (Geist, 1971).

Periodic fluctuations of population numbers about a mean is characteristic of unhunted populations. Predation acts to remove very young and very old individuals from the population while hunting removes mostly adult animals (Murie, 1944). Neither of these controlling factors appears to be operating in the In-Ko-Pah herd.

To put it another way, the energy available to support a fixed biomass of sheep appears to be tied up in older individuals with little left to support lambs.

I would then predict that lamb mortality would remain high with most losses occurring a short time after birth (2-3 months) until the older segment of the herd dies from natural mortality after which lamb recruitment (and natality) would increase. The hypothesis is testable by its predictions.

MANAGEMENT AND RESEARCH RECOMMENDATIONS

Control of Human Use

Results of the study have shown that off-road vehicle use has had a significant impact on the bighorn sheep population. Closure of roads on the east side of McCain Valley is a step in the right direction to allow for expansion of the herd. Continued study will indicate whether this action will be constructive. BLM should be prepared to revise its management scheme if the herd does not expand into the area within the next 5-10 years.

Indiscriminate use of firearms has been a factor in many reports of bighorn harassment in the area. Recent conversation with California Dept. of Fish and Game personnel has opened the possibility of banning firearms in McCain Valley except during valid hunting seasons (e.g., deer and quail). The actions would appear prudent based on the extensive vandalism in the McCain Valley area (BLM, 1978c).

Grazing should be maintained at present levels until range analysis studies are completed and the bighorn herd response to the ORV trail closures is determined. Springs that are being damaged by cattle use should be fenced using specifications now employed by the California Dept. of Fish and Game.

Habitat Management

Bighorn sheep management depends on proper habitat management, with a knowledge of physical and biological characteristics of the land (Stoddart, et al. 1955). The following points outline a range inventory and evaluation study designed to accurately measure the condition of sheep habitat in the study area:

1) Ecological classifications deal with aspects such as precipitation, topography and soils. Broadly defined vegetative communities that support sheep must be defined. Much of this work is now being completed by the BLM vegetation specialists.

2) Range-forage inventories are needed to determine grazing capacities of the study area. Special consideration should be given to those species important in bighorn diets. An excellent study by Stelfox (1976) outlines procedures directly applicable to bighorn sheep.

3) Utilization surveys are ways of assessing current grazing pressure exerted by cattle, bighorn and deer in the area. Measurement of utilization can be made through use of wire cages and exclosures, or by clipping (see McCullough 1969:102 and 127 for techniques). The utilization of annuals in the diet of bighorn is an important aspect of this study.

4) Condition and trend analyses are important range evaluations that will help determine if bighorn are reaching the carrying capacity of the habitat. Methods given by Stoddart et al. (1955) assess whether range sites are at, or depart from, acceptable standards based on their potential for production.

Bighorn Habitat Requirements

More precise data should be obtained on habitat requirements essential to bighorn survival and herd growth.

Fecal analysis results will indicate what bighorn are eating and the relative percentages of the food items in their diets. However, further food habits studies can determine if shee actually seek out specific plants or use what is most available. Todd (1972) has outlined food habits techniques used by various researchers in the study of bighorn sheep. Demarchi (1968) has reported the most essential chemical constituents required by bighorn in forage.

A technique for determining the key variables used by bighorn in habitat selection is presented by Shannon et al. (1975). The technique involves multiple regression statistics but much of the raw data has already been gathered during this study.

Hansen (in Hansen and Deming, 1975) has developed a numerical scoring method for evaluating habitat factors affecting bighorn. This method has good application to the In-Ko-Pah range.

Spring Maintenance and Development

Bighorn distribution can be expanded if more dependable water sources are available. Appendix 4 describes the springs and work needed to improve them. Developments such as those described by Halloran and Deming (1958) have been suggested for Grapevine and Blackwater Springs.

Much of the work in this area includes control of tamarisk infestations. Additional clearance of dense vegetation is needed to allow greater access to sheep.

Additional water sources should be inventoried for their output and potential importance to bighorn sheep. This is especially needed for the Jacumba Mountains.

Water developments built for sheep should follow these guidelines:

1) Developments should be located as often as possible on north-facing slopes where evaporation will be minimized.

2) Areas in solid rock should be chosen to minimize the need for concrete seepage control.

3) An area free of silt and gravel should be chosen where siltation of the tank, and thus maintenance, will be minimal.

4) The development should be located where there is more than one access route for sheep to the tank and thus minimize predation dangers.

5) Locate in area near rock ledges, outcrops and caves that can be used by sheep for shelter and protection.

Bighorn Movement and Herd Demography Studies

Priorities under this topic include more data on:

1) Lambing areas and rates to test the hypothesis and determine possible mortality factors.

2) Movements between water sources to determine whether springs have "resident" ewe bands.

3) Unknown water sources which may affect bighorn movements in the area.

The decision to artificially mark animals carries with it the philisophical argument of changing the animal's behavior patterns. There is no doubt

that marked animals (especially ewes) would greatly aid census and movement studies. The use of the helicopter to mark animals with radio collars has been discouraged because of the ruggedness of the terrain, the stress on the animals, and the chance of sheep mortality in the process. My experience with the sheep during the study has indicated that an observer on the ground can effectively approach and mark sheep in the study area.

A dye-spraying device developed by Hansen (1964) shows great promise for this area. The device has been successfully used in the Santa Rosa Mountains by Blong and Pollard (1968). Another possibility is paint pellets fired from a CO_2 pistol reported in Walker (1978). An investigator near a water hole can get close enough to bighorn where both these techniques could be effective.

The choice of methods used to census sheep if often dictated more by money and manpower than accuracy. Water hole count data collected in the In-Ko-Pahs have some inherent biases which include:

1) Unfamiliarity of the observers in spotting and identifying sheep

2) Differences in weather that affect behavior.

3) Differences in water requirements that allow sheep to keep away from water holes during the survey.

4) Difference in results obtained during months or seasons when herd composition is affected by lack of rams or lambs.

McQuivey (1978) has warned that water hole census data do not provide accurate measures of sex and age composition or population numbers. Considering the problems of the annual water hole counts in the In-Ko-Pahs, there are some redeeming factors:

1) The counts are held the same time each year.

2) The time of year (July) is likely to turn up a representative sampling of all age classes.

3) The same water holes are covered each year.

The annual water hole counts thus give good relative data between years to monitor increases or decreases in use of an area and probably give at least a rough idea of population trends. But without marked animals, the chances for duplication and error in total population estimates are great.

It is suggested that at least one intensive helicopter census be run in the fall to accurately determine the number of animals in the area. Additional helicopter time would be valuable in February to determine lambing areas.

Water hole counts should be continued in the In-Ko-Pahs but marking of animals should be attempted previous to the survey (paint marks last about 2 weeks). The opportunity exists to compare the techniques in the area and develop correction factors to account for biases in the methods.

Literature Cited

Altmann, J. 1973. Observational study of behavior: sampling methods. Behavior 49:227-265.

Bear, G. D. and G. W. Jones. 1973. History and distribution of bighorn sheep in Colorado, part 1. P-R Project W-41-R-22, Job No. 12. 232 pp.

Bennett, L. J., P. F. English, and R. McCain. 1940. A study of deer populations by use of pellet group counts. J. Wildl. Manage. 4:398-403.

Bleich, V. C. n.d. An illustrated key to aging the lambs of desert bighorn sheep. Cal. Dept. Fish and Game Rept. P.O. Box 1741, Hemet, CA 92343. 9 pp. (mimeo).

Blong, B. and W. Pollard. 1968. Summer water requirements of desert bighorn in the Santa Rosa Mountains, California, in 1965. Cal. Fish and Game 54(4):289-296.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildlife Monographs No. 4. 174 pp.

Bunch, T. D., S. R. Paul and H. McCutchin. 1978. Chronic sinusitis in the desert bighorn (Ovis canadensis nelsoni). Rept. in Phoenix Zoo files. 19 pp.

Bureau of Land Management. 1978a. McCain Valley draft recreation activity management plan. BLM, El Centro, CA. 103 pp.

Bureau of Land Management. 1978b. McCain Valley wildlife habitat management plant. BLM, Riverside District, CA. 18 pp. + figures.

Bureau of Land Management. 1978c. Feature article. BLM Newsbeat. August 1978. Sacramento. 15 pp.

California Dept. Fish and Game. 1978. Santa Rosa Mtns. bighorn sheep helicopter census results. Region 5 Monthly Report for June. 1 page.

Cheatham, N. H. and J. R. Haller. 1975. An annotated list of California habitat types. In J. Major and M. G. Barbour, Terrestrial vegetation of California. Wiley Interscience (in press).

Cowan, I. M. 1940. Distribution and variation in the native sheep of North America. Am. Midl. Nat. 24(3):505-580.

Crandall, R. 1974. Report to California Assoc. of Four-Wheel Drive Clubs, Inc. on bighorn sheep and land closures in McCain Valley. 19 pp. (typewritten).

DeForge, J. R. 1972. Man's invasion into the bighorn's habitat. Desert Bighorn Council Trans. 16: 112-115.

Demarchi, R. A. 1968. Chemical composition of bighorn winter forages. J. Range Manage. 21: 385-388.

Deming, O. V. 1952. Tooth development of the Nelson bighorn sheep. Calif. Fish and Game 28: 523-529.

Dunaway, D. J. 1971. Human disturbance as a limiting factor of Sierra Nevada bighorn sheep.

Duncan, G. E. 1960. Human encroachment on bighorn habitat. Desert Bighorn Council Trans. 4: 35-37.

Geist, V. 1967. A consequence of togetherness. Nat. Hist. 76(8)24, 29-30.

Geist, V. 1971. Mountain sheep: a study in behavior and evolution. Univ. of Chicago Press. Chicago. 383 pp.

Geist, V. 1975. On the management of mountain sheep: theoretical considerations. Pages 77-105 In J. B. Trefethen, ed. The wild sheep in modern North America. Winchester Press, New York.

Halloran, A. F. and O. V. Deming. 1958. Water development for desert bighorn sheep. J. Wildl. Manage. 22(1): 1-9.

Hansen, C. G. 1964. A dye spraying device for marking desert bighorn sheep. J. Wildl. Manage. 28(3): 584-587.

Hansen, C. G. 1967. Bighorn sheep populations of the desert game range. J. Wildl. Manage. 31(4): 693-706.

Hansen, C. G. 1971. Overpopulation as a factor in reducing desert bighorn populations. Desert Bighorn Council Trans. 15: 46-52.

Hansen, C. G. and O. V. Deming. 1973. Reproduction. Chapter 9 In Desert Bighorn Council. The desert bighorn, its life history, ecology and management. Preliminary manuscript.

Hicks, L. L. 1977. Human disturbance of the Mt. Baxter herd of Sierra Nevada bighorn sheep. Unpubl. Master's thesis. Univ. of Michigan, Ann Arbor. 57 pp.

Jorgensen, M. C. and R. E. Turner, Jr. 1973. The desert bighorn sheep of Anza-Borrego Desert State Park. Desert Bighorn Council Trans. 17: 81-88.

Jorgensen, P. 1974. Vehicle use at a desert bighorn watering area. Desert Bighorn Council Trans. 18: 18-24.

Light, J. T., Jr. and R. Weaver. 1973. Report on bighorn sheep habitat study in the area for which an application was made to expand the Mt. Baldy winter sports facility. Cajon Ranger District, San Bernardino National Forest, U.S. Forest Service. 39 pp. (mimeo).

McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. Univ. Calif. Press, Berkeley. 209 pp.

McQuivey, R. P. 1978. The desert bighorn sheep of Nevada. Nevada Dept. Fish and Game. Biol. Bull. 6. 81 pp.

Merritt, M. F. 1974. Measurement of utilization of bighorn sheep habitat in the Santa Rosa Mtns. Desert Bighorn Council Trans. 18: 4-17.

Murie, A. 1944. The wolves of Mt. McKinley. U.S. National Parks, Fauna Series No. 5. 238 pp.

Nelson, M. 1966. Problems of recreational use of game ranges. Desert Bighorn Council Trans. 10: 13-20.

Olech, L. A. 1978. The behavior of the peninsular bighorn sheep, Ovis canadensis cremnobates Elliot, in Anza-Borrego Desert State Park, California. Unpubl. Master's thesis. 120 pp.

Phillips, E. A. 1959. Methods of vegetation study. Holt, Rinehart and Winston, Inc., New York. 107 pp.

Russi, T. L. and R. E. Monroe. 1976. Parasitism of bighorn sheep in Anza-Borrego Desert State Park, California. Desert Bighorn Council Trans. 20: 36-39.

Russi, T. L. 1978. Notes on a group of peninsular bighorn. Desert Bighorn Council Trans. In press. 7 pp.

Russo, J. P. 1956. The desert bighorn sheep in Arizona. Ariz. Game and Fish Dept. Wildl. Bull. 1. 153 pp.

Schultz, R. D. and J. A. Bailey. 1978. Responses of national park elk to human activity. J. Wildl. Manage. 42(1): 91-100.

Seegmiller, R. F. 1977. Ecological relationships of feral burros and desert bighorn sheep, Western Arizona. Unpubl. Master's thesis. Ariz. State Univ., Tempe. 135 pp.

Shannon, N. H., R. J. Hudson, V. C. Brink, and W. D. Kitts. 1975. Determinants of spatial distribution of Rocky Mountain bighorn sheep. J. Wildl. Manage. 39(2): 387-401.

Singer, F. J. 1978. Behavior of mountain goats in relation to U.S. Highway 2, Glacier National Park, Montana. J. Wildl. Manage. 42(3): 591-597.

Smith, D. R. 1954. The bighorn sheep in Idaho. Idaho Dept. Fish and Game. Wildl. Bull. No. 1. 154 pp.

Stankey, G. H., R. C. Lucas and D. W. Lime. 1976. Crowding in parks and wilderness. Design and environment 7(3): 38-41.

Stelfox, J. G. 1976. Range ecology of Rocky Mountain bighorn sheep. Canadian Wildlife Service Report No. 39. 50 pp.

Stoddart, L. A., A. D. Smith, and T. W. Box. 1975. Range Management. 3rd ed. McGraw-Hill Co., New York. 532 pp.

Tennesen, M. 1975. Bighorn on the run. National Wildlife Oct.-Nov. issue. pp. 4-10.

Todd, J. W. 1972. A literature review on bighorn sheep food habits. Special Rept. No. 27, Colorado Dept. of Fish, Game and Parks. Coop. Wildl. Research Unit. 21 pp.

Turner, J. C. 1973. Water, energy, and electrolyte balance in the desert bighorn sheep, Ovis canadensis. Ph.D. Dissertation, Univ. of California, Riverside. 114 pp.

Van Den Akker, J. B. 1960. Human encroachment on bighorn habitat. Desert Bighorn Council Trans. 3: 38-40.

Walker, M. T. and R. D. Ohmart. 1978. The peregrinations and behavior of feral burros (Equus asinus) which affect their distribution area and population size in the Havasu Resource Area, Colorado River Valley, California-Arizona. Rept. to Bureau of Land Management. 99 pp.

Ward, A. L., J. J. Cupal, A. L. Lea, C. A. Oakley, and R. W. Weeks. 1973. Elk behavior in relation to cattle grazing, forest recreation, and traffic. Trans. N. Am. Wildl. Conf. 38: 327-337.

Wehausen, J. D., L. L. Hicks, D. P. Garber, and J. Elder. 1977. Bighorn sheep management in the Sierra Nevada. Desert Bighorn Council Trans. 21: 30-32.

Welles, R. E. and F. B. Welles. 1961. The bighorn of Death Valley. U.S. National Parks, Fauna Series No. 6. 241 pp.

Welsh, G. 1971. Our bighorn sheep - what is happening to them? Ariz. Game and Fish Dept. Wildlife Views 18(5): 10-17.

Wilson, L. O. 1969. The forgotten desert bighorn habitat requirement. Desert Bighorn Council Trans. 13: 108-113.

Appendix 1. Location of ORV overlooks sampled by pellet transects

Transect No.	Name	Location
1	Cimarron	T16S R7E SW1/4 SW1/4 Sec 26
2	Grunt	T16S R7E SW1/4 NW1/4 Sec 26
3	Jacumba Jim 1	T16S R7E NE1/4 SE1/4 Sec 22
4	Jacumba Jim 2	T16S R7E SE1/4 SE1/4 Sec 22
5	Rattlesnake	T16S R7E NW1/4 NW1/4 Sec 35
6	Jacumba Jim 3	T16S R7E NE1/4 NE1/4 Sec 22